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The Water Footprint Assessment of Ethanol Production from Molasses in Kanchanaburi and Supanburi Province of Thailand.

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Abstract

This study aims to assess water footprint of ethanol production from molasses in Kanchanaburi and Suphanburi Provinces of Thailand, based on the water footprint concept methodology.
The water footprint of ethanol from molasses can be calculated into three parts: sugar cane, molasses, and ethanol production. The green, blue, and grey water footprints of ethanol production from molasses in the Kanchanaburi Province are 849.7, 209.6, and 45.0 (m^3/ton), respectively, whereas those of ethanol in the Suphanburi Province are 708.3, 102.9, and 64.8 (m^3/ton), respectively. Study results depend on several factors such as climate, soil, and planting date. These are related and effective to the size of water footprint. Especially, if schedule of planting and harvest date are different, which causes the volume of rainfall to be different; these affect the size of water footprints. A limitation of calculation of grey water footprint from crop process has been based on a consideration rate of nitrogen only. Both provinces in the study area have their respective amount of the grey water footprint of molasses, and ethanol production is zero. The wastewater in molasses and ethanol production have a very high temperature and BOD, whereas the grey water footprint in this study is zero because the wastewater may be stored in pond, or it may be reused in area of factory and does not have a direct discharge into the water system. However, there is a risk for soil and ground water pollution.

Keywords: water footprint, sugar cane, molasses, ethanol production

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1. Introduction

Awareness on global warming and climate change has led to the adaption of low-carbon energy and has an effect in the determination of the direction and energy policies of various countries around the world. Thailand is an agricultural country that has agricultural production as well as high potential agricultural residues that can be used as renewable energy such as oil palm, sugar cane, cassava, and corn. Therefore, the government determines the strategic development of renewable energy [1]. One of the means to promote renewable energy is ethanol production, which can produce gasohol. To respond to these factors should be to increase the production of ethanol. Considering the economic value, feedstock for the ethanol industry in the country includes molasses and cassava [2] [3]. Sugar cane is a food plant that will become an energy plant [3] because it produces not only sugar as the main product but also pulp and molasses; these are produced indirectly (by-product) for the production of energy. Molasses are used for ethanol production [4] [5] with pure ethanol (99.5%), which is to be mixed with gasoline to produce fuel gas, also known as gasohol. When the needs of plants and energy plants increase, it results in the increase of the competition of water use. Cultivation of biomass sources to replace fossil fuels has a large influence on the demand for more water resources in the future. The production of renewable energy from biomass that relates to the use of water has two parts: cultivation and conversion to energy. This also includes competing with other communities or industries for the benefits [6] as the water environment starts to deteriorate. Water footprint is an indicator of freshwater use from various sources, whether direct or indirect suppliers or consumers throughout the chain production [7]. The water footprint shows the source and volume of water. It is useful for the appropriate water resources management and reduces the water resources' stress.This study aims to assess the water footprint of ethanol production from molasses. Water use has two main parts as for crop growth and ethanol production process. The selected study area is in the central region of Thailand because this region uses water for various activities. Most industrial estates and agricultural lands are found in this Thailand area, and the population is most dense [8][9][10], although the quality of water deteriorates every year [11]. Kanchanaburi and Suphanburi Provinces were selected as study areas because both provinces have the most number of crop areas and yields [12] and are the location of factories that produce ethanol from molasses. The final results show the water footprint of ethanol production from molasses throughout the production chain. Data from these results can be used as the basis for managing water resources not only in Thailand but also in other regions.

2. Method and Data

2.1. Method

The objective of this study is to assess water footprint of ethanol production from molasses in Kanchanaburi and Suphanburi Provinces of Thailand based on the methodology described by [13]. As assessment of water footprint will share the assessment of all chain production, the two main parts are the crop and the product. The first part, water footprint of the crop, can be used as a water footprint of the input product to calculate the water footprints of the following products. The final result is a water footprint of ethanol production from molasses. The water footprint of the crop is the sum of the green, blue, and grey components. The green and blue water footprints is calculated as crop water use (CWU, m3/ha) divided by the crop yield (Y, ton/ha), (Equation 1). CWU is calculated by the accumulation of daily evapotranspiration (ET, mm/day) over the complete growing period. Evapotranspiration is estimated by the CROPWAT model

$$WF_{green,but} = \frac{CWU_{green,blue}}{Y} = \frac{10 \times \sum_{d=1}^{lgp} ET_{green,blue}}{Y} \tag{1}$$

The grey water footprint of the crop is calculated as Equation 2. The chemical rate to the field per hectare (AR, kg/ha) multiplied by the fraction of nitrogen that leaches or runs off by the nitrogen application rate (∞,kg/ha) and divide this by the difference between the maximum acceptable concentration of nitrogen (Cmax, kg/m3) and the natural concentration of nitrogen in the receiving water body (Cnat, kg/m3) and by the actual crop yield (ton/ha)

$$WF_{proc,grey} = \frac{(\alpha \times AR)/(C_{\max} - C_{nat})}{Y} \qquad (2)$$

Pollutants leaching from the crop are the main cause of nonpoint source pollution of the surface and subsurface water bodies. In this study, the chemical rate of the nitrogen that is used only in the chemical fertilizer application to the field is considered.

The water footprint of the product can be calculated in two alternatives and breaks down into green blue and grey component [13]. This study uses the stepwise accumulative approach. First step, calculate the water footprint of molasses by-product from sugar production, the input product of which is sugar from the crop. Next, calculate ethanol production in a manner similar to the first step; the input product can be changed to molasses from the former production. Green and blue water footprints can be separated as water footprint of the input product. The water footprint of the product is calculated as Equation 3

$$WFprod[p] = \left(WFproc[p] + \sum_i^y \frac{WFprod[i]}{f_p[p,i]} \right) \times f_v[p] \qquad (3)$$

Where WFprod[p] is the water footprint (volume/mass) of the output product, WFproc[p] is the water footprint of the processing step in water use per unit of input (volume/mass), WFprod[i] is the water footprint of the input product, and fp[p,i] is the product fraction of the output. The value fraction (fv[p]) of molasses and ethanol was taken from [14]. Last step, the grey water footprint can be calculate by pollution load, which is the volume of water body factor pollutant load concentration divided by the quality water standard minus the natural concentration as allocation.

2.2. Data

The calculation of water footprint of the crop has been done using the climate data from the nearest and the most representative meteorological station located [15] in the study area. The crop parameters are obtained from [16]. Soil data can use from [17]. Data on the average harvest area (ha) and yield of sugar cane (ton/ha) were from [12]. Data used for calculating the water footprint of the product, such as molasses and ethanol, have been collected based on an interview by an officer associated in the industrial process.

3. Result

The water footprint of ethanol from molasses is calculated into three parts. For the first part, both results of water use during sugar cane growth as water footprint of the crop in Kanchanaburi and Suphanburi Province of Thailand showed an approximate total of water footprint of the sugar cane, as shown in Table 1

Table 1. Water footprint of sugar cane (m^3/ton)

Province	Water Footprint of sugar cane (m^3/ton)			
	Green	**Blue**	**Grey**	**total**
Kanchanaburi	138.8	33.9	45.0	217.7
Supanburi	134.2	19.2	64.8	218.2

The second part is calculating the water footprint of molasses production. Molasses is a by-product of sugar processing, and this can produce ethanol. Thus, only molasses production is calculated separately. The green and blue water footprint of molasses in the Kanchanaburi Province are 172.3 and 142.0 (m3/ton), respectively, whereas the green and blue water footprint of molasses in the Suphanburi Province is 139.7 and 20.0 (m3/ton), respectively. At the last part, calculation of the water footprint of ethanol production in Kanchanaburi and Suphanburi Provinces is by estimating the second part; the green and blue water footprint of ethanol in the Kanchanaburi Province is 849.7 and 209.7 (m3/ton), respectively, whereas the green and blue water footprint of ethanol in the Suphanburi Province is 708.3 and 102.9 (m3/ton), respectively. Next is converting a liter of ethanol to a ton of ethanol used; the density of ethanol is 0.789 kg/L [14]. In both provinces, the grey water footprint of molasses and ethanol is zero.

4. Conclusions and discussion

The result in this study, the total amount of the green and blue water footprint of sugar cane in Kanchanaburi and Suphanburi Provinces is 172.7 and 153.4 m3/ton, respectively. In comparing these results, the global total amount of the blue and green water footprint estimated is 196 m3/ton [18], whereas [19] the global average of water footprint of sugar cane is 209 m3/ton. According to Salvatore and Damen [20], who conducted a study in Thailand, a different province has water footprint of sugar cane, which is 146 m3/ton. Kanchanaburi has more blue water footprint of sugar cane than the Suphanburi, although the agriculturists of Suphanburi province use water from the blue water more than those in Kanchanaburi because the former province has an efficient water resource management. Thus, Suphanburi is appropriate to support the crop area. The result of the study should be determined by other factors. It can be seen that the factors in a distinct area—as climate, soil, and planting date are effective to the size of the water footprint. In particular, if schedule of planting date is different, the volume of rainfall would be different, and this has an effect on the size of water footprintt. In practice, the properties of the soil will not influence the selected area to plant sugar cane in the country. Thus, the selected soil property of the crop area to represent the "medium option" follows [13]. The secondary data in this study were collect by a different state agency. The various sources of data such as period of data result in the varying size of water footprint. A limitation is the calculation of grey water footprint that has to based on a consideration of nitrogen only; this is important because agriculturists use pesticides and herbicides and choose fertilizer depending on their preference and not on the needs of the plants. This results in the varying amount of grey water footprint. The wastewater in molasses and ethanol production is very high temperature and BOD, whereas the grey water footprint in this study is zero because of the wastewater that may be stored in a pond or reused in an area of the factory and does not have a direct discharge into the water system. That is a risk for soil and ground water pollution [20].

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